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ABSTRACT

A series of experiments investigated 5- to 17-month-olds' comprehension of adults' direction of gaze and manual pointing behaviors. Findings indicated that a change in the adult's direction of gaze and orientation of head does not seem sufficient to enable the infant to reliably localize a referent when the infant must choose between pairs of identical targets on the same side of the visual field. Strong evidence for comprehension of referential communication was obtained when the adult not only looked but also pointed at the correct target. Babies of 10 months and older accurately localized the target regardless of whether it was to the right or left of the visual field, even when a competing, identical target had to be ignored. Tentative evidence indicated that the ability to comprehend pointing may first arise for targets in the right side of the field of vision between 5 and 9 months of age, and may become bilateral toward the end of the first year. (Author/RH)

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Evidence for the "geometric" comprehension of manual pointing.

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Abstract

A series of 4 experiments is reported on comprehension of an adult's direction of gaze and manual pointing in babies aged 5 to 17 months,

In general, a change in the adult's direction of gaze and orientation of the head does not seem sufficient for the infant reliably to localise the referent when a choice must be made between pairs of identical targets on the same side of the visual field. Strong evidence for comprehension of referential communication is obtained however, when the adult not only looks but also points manually at the correct target. Now, the older babies (from approximately 10 months), accurately localise the target whether to the right or left of the visual field, even when a competing, identical target must be ignored. We obtained tentative evidence that the ability to comprehend pointing may first arise for targets in the right side of the field of vision, at sometime between 5 and 9 months, to become bilateral toward the end of the first year of life.

Our theoretical interpretation of these results is that a change in the orientation of visual attention of the adult informs infants at all the ages studied of the **direction** (left/right) in which to look. However, identifying the precise **location** within either hemifield may depend on development of a "geometric" cognitive mechanism. The "geometric" process allows the infant to localise the object of the adult's attention by extrapolating a trajectory from the pointing hand into a fairly precise region of the infant's own visual space.

Younger babies (5-9 months) are not in possession of this "geometric" mechanism nor do they comprehend the referential significance of manual pointing under all the conditions of our experiments. However, the performance of babies as young as 5 months can be enhanced if the targets provide intrinsic attention cues, such as movement. We obtained evidence that target movement may help the younger baby to extrapolate from the pointing hand to the referent and it also helps the infant interpret more precisely the referent of the adults gaze. The implication is that ecological factors, such as object movement, may be important in ensuring joint visual attention and preverbal communication with young babies.

Introduction

This paper is concerned with the spatial properties of visual attention and the associated postures of the human head and hand which signal, for another person, the existence of a potential object for their joint attention . Joint visual attention, or deictic gaze as it is also called, may be defined simply as "looking where someone else is looking". Deictic gaze is thought to pave the way in human development for deictic gestures, such as manual pointing, which draw attention to a particular object and offers one of the bases in shared experience for the acquisition of language (Bruner 1983).

In some early studies of the mechanisms of joint visual attention we found that at six months, babies look to the correct side of the room, as if to see what the mother is looking at , but they cannot tell on the basis of the mother's action alone to which of two identical targets the mother is attending, even with angular separations as large as 60 degrees between the targets, (Butterworth and Cochran (1980) and Butterworth and Jarrett (1991)). It is as if the adult's change of visual orientation specifies the direction (left or right) in which the baby should look but not the precise location within the visual hemi-field. Between twelve and eighteen months however, the infant is beginning to localise the targets correctly when the only information allowing this is the angular displacement of the mother's head and eye. These data suggest that a new ability may arise toward the end of the first year, whereby the infant from her own position, can single out not only the direction but also the location at the focus of attention of another person. This ability is what we define as a "geometric " solution since it would seem to require the infant to extrapolate an invisible path from the angular orientation of the adult to the correct target in the field of view. However, our evidence for this ability was based on only one pair of

target locations separated by 60 degrees of visual angle relative to the infant with the identical alternate targets rather near the baby. The main aim of the present research project was to make more exhaustive tests to establish whether and when a "geometric" ability to localise spatially the referent of the adult's action arises in early cognitive development .

It is generally agreed that comprehension of manual pointing occurs toward the end of the first year, somewhat in advance of production of the gesture, (Schaffer 1984). Grover (1988) compared the adult looking with looking and pointing to a target and found that babies were significantly more likely to respond to the signal of manual pointing than to a change of gaze alone (see Butterworth and Grover 1988). Manual pointing has a compelling effect on infant attention but it is not known whether pointing increases the infant's accuracy in localising the referent. A second aim was to find out more about the relation between comprehension of gaze, aspects of which which occur relatively early in development and the later appearing species specific ability to comprehend manual pointing .

General methodology of the comprehension studies

Many aspects of the experiments and procedure were constant and will be described first in general terms. The sample of infants was recruited through advertising and material sent to nursery schools, mother's and toddler's groups and "well baby" clinics in the region . In the comprehension studies infants were in 3 age groups arbitrarily defined as the 'younger' (6 to 9 months); 'middle' (10 to 13 months) and 'older' group (14 to 17 months).

Apparatus and Procedure

A laboratory with video-recording equipment was constructed within the Department of Psychology. This comprised a large room whose walls were lined with cream coloured curtaining to provide a homogeneous environment. Video-recording was done with two cameras hidden behind the laboratory curtains, one of which provided a general view of the adult and infant and the other which gave a close up of the infant. Adult and infant were seated with their eyes at approximately the same level. Targets in the form of identical manikins were presented in pairs at various visual angles and distances relative to the infant. The manikins were 43 cms tall, set on a stand at a height of 138 cms. The arms and legs of the manikins could be set in motion, by remote control, in a sequence of up and down movements of 7 seconds duration.

Procedure

The procedure involved the mother (or experimenter) gaining rapport with the baby. Then, the adult would turn deliberately and look (or look and point) at one of the targets for approximately 6 seconds. The particular target to be singled out on any trial was designated by a light box under the infant's chair, visible to the adult but not visible to the baby. The targets were always stationary during each trial (except in experiment 4) and they

were clearly visible to the infant. The first target along the infant's scan path from the adult was at 10 degrees. The second target was always at a more peripheral position and locating it would require the baby to select it instead of the first (identical) target. The visual angle separating the alternate targets, relative to the infant, varied between 25 and 55 degrees in six degree steps. The absolute distance between targets could be varied, as could their distance from the infant. The pairs of targets were always presented in random order of angular separation and the order of conditions (looking v looking and pointing) was randomly assigned.

Once the infant made a response and was fixating one of the two manikins, both targets were moved simultaneously by remote control. Introducing movement of the arms and legs of the manikins immediately after each trial served to maintain motivation and interest. The experiments usually lasted from 15 to 20 minutes.

Scoring procedures

The scoring of video recordings was done separately by the investigator and by an independent observer who noted the infant's eye position when fixating a target. The inter-observer reliability accepted for purposes of data analysis on the scoring system was 95% to 100% agreement on the coding category.

The following codes were used to classify infant responses in all experiments, using frame-by-frame analysis of the video recordings :-

Correct (C) - mother follows instructions correctly and the infant fixates the target indicated by the mother; there were three variations within this score, as follow:-

(1) the infant fixates the target indicated by the mother then s/he checks back to where mother is looking and the infant fixates again the target

indicated by the mother;

(2) the infant fixates the target indicated by the mother then s/he briefly looks at the alternate target and the infant fixates the target indicated by the mother again;

(3) the infant fixates the target indicated by the mother then s/he briefly looks at the alternate target, checks the mother and the infant again fixates the target indicated by the mother.

Wrong (W) - mother follows instructions correctly and the infant fixates a target not indicated by the mother; there was one variation within this score, as follows:-

(1) the infant appears to fixate mother's finger or arm and not the target.

Uncertain (U) - the infant fixates the target indicated by the mother BUT shifts from one target to the other most of the trial.

Void (-) - mother does not follow instructions correctly, i.e. no rapport established (initial eye contact) and mother gives verbal clues.

There was another source of void data which occurred when the targets were accidentally set in motion before the infant fixated one of them.

No Response (0) - infant looks away, stares or otherwise distracts him or herself.

Data analyses were carried out on the agreed scores, using both non-parametric and parametric tests.

Experiment 1.

Subjects

Sixty one subjects were recruited of whom 48 were eventually tested (Male 25, Female 23). These were assigned to three groups 6-9 months

Mean age 195.5 days SD 74. 5 days, 10-13 months Mean 358.9 days SD 39.4 days and 14-17months, mean 478 days SD 57.7 days).

Experimental design

The experimental design is summarised in Figure 1. The targets were presented in pairs, on a semicircular distribution at 2.76 metres from the baby. The visual angles relative to the infant were 10 and 65 degrees; 10 and 59;10 and 53; 10 and 47;10 and 41; and 10 and 35 degrees. The absolute distance between targets varied. In order to test accuracy over this range of angles and to be able to video-record satisfactorily, it was necessary to present targets in the left half of the visual field .

Results

The majority of responses to the 10 degree target, the first to be encountered by the infant on the scan path from the mother were correct at all ages, whether the mother looked or looked and pointed at it. However, the experiment produced little if any evidence for significantly correct selection of the second target along the scan path, at any of the ages or any of the angles tested when the mother simply looed at the target.

A rather different pattern of results is obtained however, when the mother not only looked but also pointed manually at the correct target. The middle and oldest age groups had a majority of their overall responses correct to the second target along the scan path when the mother looks and points. The detailed breakdown by angular separation reveals a fairly complex picture illustrated in the graphs shown in Figs 1 a-c. The oldest and intermediate aged groups of infants are accurate at angular separations between 31 and 49 degrees. The youngest babies (Group 1) give no

evidence for statistically accurate localisation of the second target. even with the addition of pointing.

Discussion.

We did not obtain strong evidence that a change in direction of gaze alone is sufficient for the infant to localise the target. However, adding pointing gives evidence for spatial localisation of the alternate target in babies aged from 10 months. The results show that comprehension of pointing involves knowing not only in which direction to look but also that a particular location is being singled out. A second experiment was carried out to control the angular distance from the infant with the separation between targets held constant.

Experiment 2. A further test of the geometric localisation hypothesis.

Subjects

Only the older group (14 to 17 months) was recruited (N=24) since this group in the previous experiment gave the strongest evidence for possession of the geometric mechanism.

Their average age was 477.09 days SD 47.58 days (Males N=11 Females N= 13)

Apparatus and Procedure

Targets were manikins, the same as in the previous study. To achieve greater precision of target specification, the investigator took the place of the mother in this study. The experimental design is summarised in Figure 2. Pairs of targets were presented in random order. One set of pairs replicated the previous study in being presented at a constant distance of

2.7 meters and at 10 and 59 degrees, 10 and 47 degrees, 10 and 35 degrees. However, a new set of positions was introduced whereby the angular separations and distance between targets were held constant between experiments 1 and 2 but the distance of the more peripheral target from the infant was systematically increased. This was achieved by "rotating" the more peripheral target around the 10 degree target, to a new position. Thus a new 10 and 47 degree pair was created by "rotating" the 2.7 metre 59 degree position around the 10 degree target, until it crossed the 47 degree angle from the infants' midline. This was repeated for 10 and 35 degrees (rotated from the 2.7 metre 59 degrees position) and 10 and 35 (rotated from the 2.7 metre 47 degrees position). Thus , the visual angle separating the alternate targets varied between 25 and 49 degrees. The distance from the infant's midline to the target at 10 degrees was kept at 2.76m but the distance of the target at 47 and 35 degrees varied between 2.76 metres and 3.7 metres. (Figure 2 makes the arrangement of the laboratory clear).

Results

The data confirm the results of the previous experiment in that strong evidence for a geometric process is obtained only when the adult looks and points at the target. Infants accurately locate the second target at about 3.7 metres and only 25 degrees separate from the first target they see. This is expressed graphically in Figure 2a.

Discussion.

Infants can distinguish which of two targets is being indicated, so long as manual pointing is involved, even when the angular separation between them is as little as 25 degrees at a distance from the infant of 3.7 metres. The difference in the position of the pointing hand at this angular

separation is very small indeed. Since infants can accurately locate the alternate at such a small angular separation the results suggest that either a very narrow conical projection is extrapolated to the target or , more likely, the infant can extrapolate a straight line from the pointing hand rather precisely into the visual field to single out the object of the adult's attention. The ability to extrapolate a trajectory into visual space is what we mean by a "geometric" mechanism.

Experiment 3. Comparisons between performance in the left and right hand sides of the visual field.

Introduction

Having established that a "geometric" process does seem implicated in the performance of the older two groups of babies, we carried out a third study whose specific purpose was to compare performance in each visual hemifield.

Subjects.

A new group of 48 infants was tested (16 in each age group 5-9 months (Mean age 211, SD 44.48 days), 10-13 months(Mean age 363.43 SD 35.13 days), and 14-17 months (Mean age 465.45 SD 48 days).

Apparatus and procedure.

The experimental design is summarised in Figure 3. The mother and infant were seated in the middle of the laboratory and targets were presented in pairs, either to the left or right. The distance of the targets from the infant was 2.76 metres on a semi-circle about the baby and the angular separation was 10 and 65 degrees, 10 and 47 degrees and 10 and 41 degrees to the left (or right) of the infant's midline. The pairs of targets

were presented in random order, counterbalanced for sides of the room .

Results.

Once again, adding pointing reveals statistically accurate localisation of the more peripheral alternate whereas looking alone does not.. However, there also seems to be a visual field effect, since the majority of infants in all age groups accurately localise the alternate target when it is in the right visual field, whereas only the oldest and intermediate age group do so when the target is in the left visual field. These effects are shown graphically in Figures 3.a and 3.b

In summary, the non-parametric analyses suggested that infants may comprehend pointing geometrically for targets on the right hand side of the visual field at an earlier age than for the left. This conclusion was supported equivocally by parametric tests where a right side advantage for the two groups of younger infants approached significance. The results are therefore suggestive but require replication in a strictly symmetrical environment.

Experiment 4: The effect of target movement on the comprehension of reference by younger infants.

The fact that geometrically accurate comprehension of pointing seems to arise later in development need not mean that younger babies lack the capacity for comprehending the referential looking behaviour of an adult. Even the youngest group may be able to single out the referent of the mother's head and eye movement if it has some intrinsic, attention worthy property, (Butterworth and Grover 1988).

Subjects

In a fourth experiment, a new set of 32 infants from the youngest (6-9 months Mean Age 229 days SD 22.77 days) and intermediate age groups (10-12 months, Mean age 352 days SD 36.48 days) was tested.

Apparatus and Procedure

The same manikin targets described above were presented as a single pair, at fixed spatial position relative to the mother and infant. The 10 degrees and 65 degrees positions were chosen; i.e., the visual angle separating the two targets was constant at 55 degrees to the left , at a distance of 2.76 metres from the infant's midline. The experimental layout is shown in Figure 4. Three experimental conditions and one control condition were presented in random order:

Condition 1.

First target along scan path (10 degrees) moving and the second target (65 degrees) stationary.

Condition 2 .

First target along the infant's scan path stationary and the second target moving.

Condition 3.

Both targets moving simultaneously.

Condition 4 .

Control: both targets stationary.

The procedure was very carefully controlled so that target movement was not initiated by the experimenter until after the infant had begun to respond to the adult's signal and before the infant's response had terminated. The experimenter took the place of the mother to gain better control over eye contact with the infant and the onset of target movement.

Results

Fig 4. show that when the adult looks, the youngest group locate the correct target if it is moving but not if it is stationary. The intermediate age group also locate the correct target when it is moving. There was some

evidence that putting both targets into simultaneous motion may actually enhance accuracy to the second, peripheral target. Adding pointing aids even the youngest infants to respond to the correct target when it is first along the scan path and/or in motion. However, pointing does not assist the youngest infants to isolate the more peripheral referent at 65 degrees when both targets are stationary. An unexpected result was that motion in both targets helps the youngest babies locate the correct target at 10 or 65 degrees. The intermediate age group show the same overall pattern of results. The series of graphs in Fig 4a to 4d illustrate the effects of target movement on performance.

Motion in the alternate target assists the infant to locate it, even when the adult merely looks at it, a signal that is not usually sufficient for spatial localisation among the youngest infants . Of course, the prepotency of motion also leads the infant into erroneous localisation when the moving target is put into conflict with the actual location of the adult's gaze. Interestingly, however the combination of movement in the target, with manual pointing by the adult, seems to assist infants to localise the referent of the pointing hand.

Conclusion

Our studies clarify a number of phenomena concerning the relation betwen comprehension of gaze and of manual pointing. First, they demonstrate that comprehension of pointing may depend on an elementary "geometric" ability whereby the infant becomes able to extrapolate trajectories between positions in space. This may correspond, in a social setting, to what Piaget described as the ability to solve invisible displacements (Piaget 1954).

The experiments replicated three times the beneficial signalling effect of adding pointing to a simple change of gaze, at least from 10-12 months. Infants can accurately locate the target at spatial separations as small as 25 degrees, at different distances , so long as they have the benefit of information from the pointing arm. In our previous studies we did obtain some evidence for a "geometric" mechanism to gaze alone but this was in a very small room where the alternate targets were close to the baby. Under the more extended spatial conditions of the present study, it seems that the extended arm provided the information required by the infant to localise the referent. It seems likely that the arm assists because for any given spatial separation, the excursion of the extended index finger between alternates is much greater than the head and eyes and this may help to single out the referent. We obtained some rather tentative evidence that this "geometric" ability may first arise for targets in the right hand side of the field of view before it becomes available bilaterally. It would be necessary to carry out further studies with babies in the 5 to 9 month age group to determine whether comprehension of manual pointing is initially lateralised. The results do suggest that an apprenticeship in looking where some one else is looking is insufficient for comprehension of pointing.

Rather, the acquisition of the geometric during the latter part of the first year of life seems to be a condition for the comprehension of pointing.

Second, we demonstrated that ecologically relevant characteristics of the objects in the environment, such as motion, contribute to early communication because having been given a signal concerning the direction in which to look by the adult, such characteristics are a potent means whereby the object itself captures the infant's attention. This could have important implications for how babies come to understand the signal functions of pointing in everyday life. The attention compelling characteristics of objects in the natural environment may lead the child away from fixating the adults' hand toward the target. Development of the "geometric" ability to extrapolate a trajectory from the hand to the target would then enable the precision of localisation we observe in our studies.What may be dismissed as mere distractability when attention is considered in social isolation, may be seen in social context to have a basic communication function hence assist the infant to acquire an understanding of the significance of index finger pointing.

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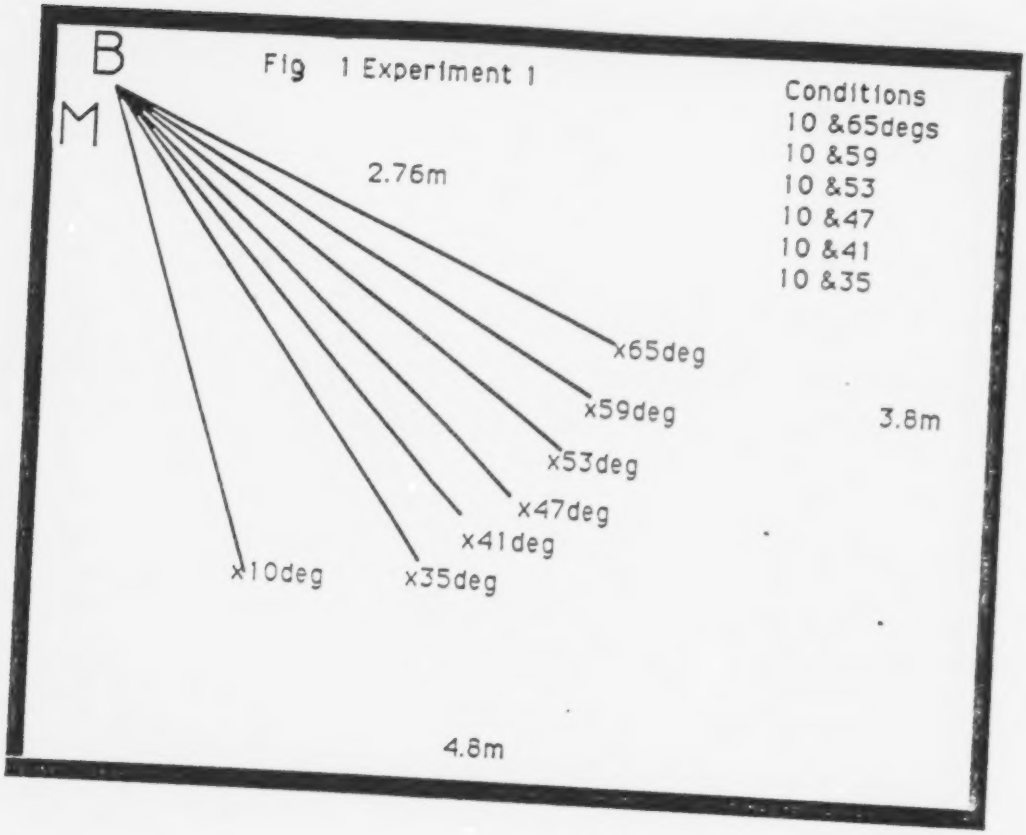
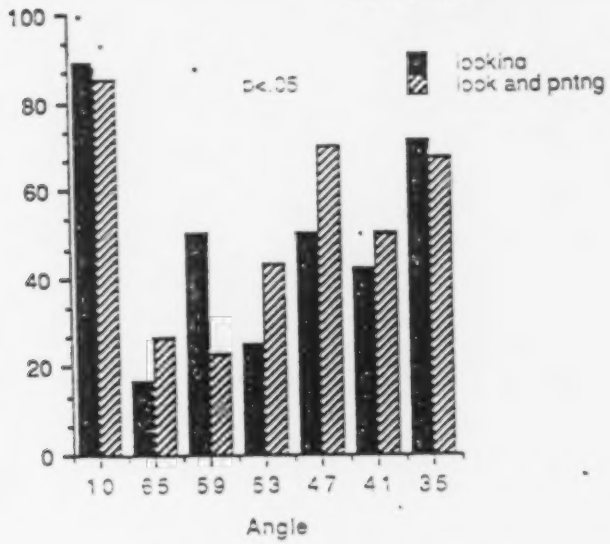
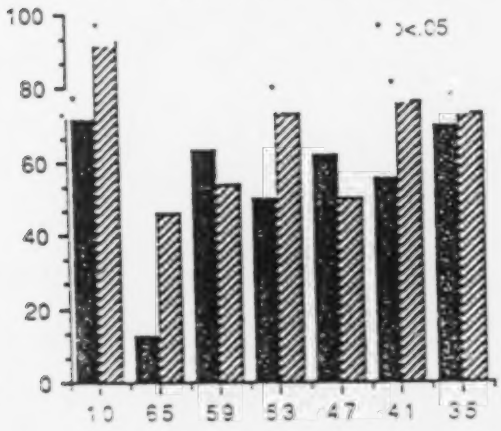

B
M
Fig 1 Experiment 1
Conditions
10 &65degs
10 &59
10 &53
10 &47
10 &41
10 &35
2.76m
x65deg
x59deg
x53deg
x47deg
x41deg
x35deg
x10deg
3.8m
4.8m

19

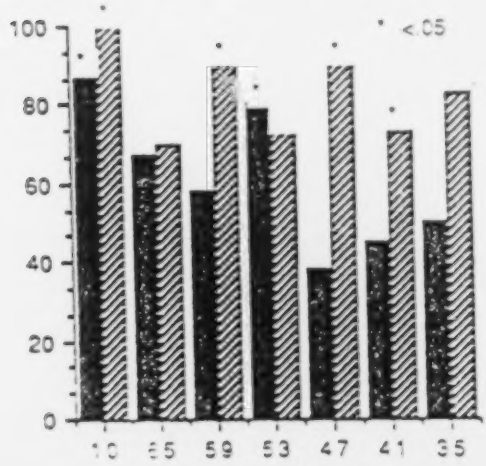
%C/C+W Fig 1a % correct responses
5-9 months



%C/C+W Fig 1b 10-13 months



%C/C+W Fig 1c 14-17 months



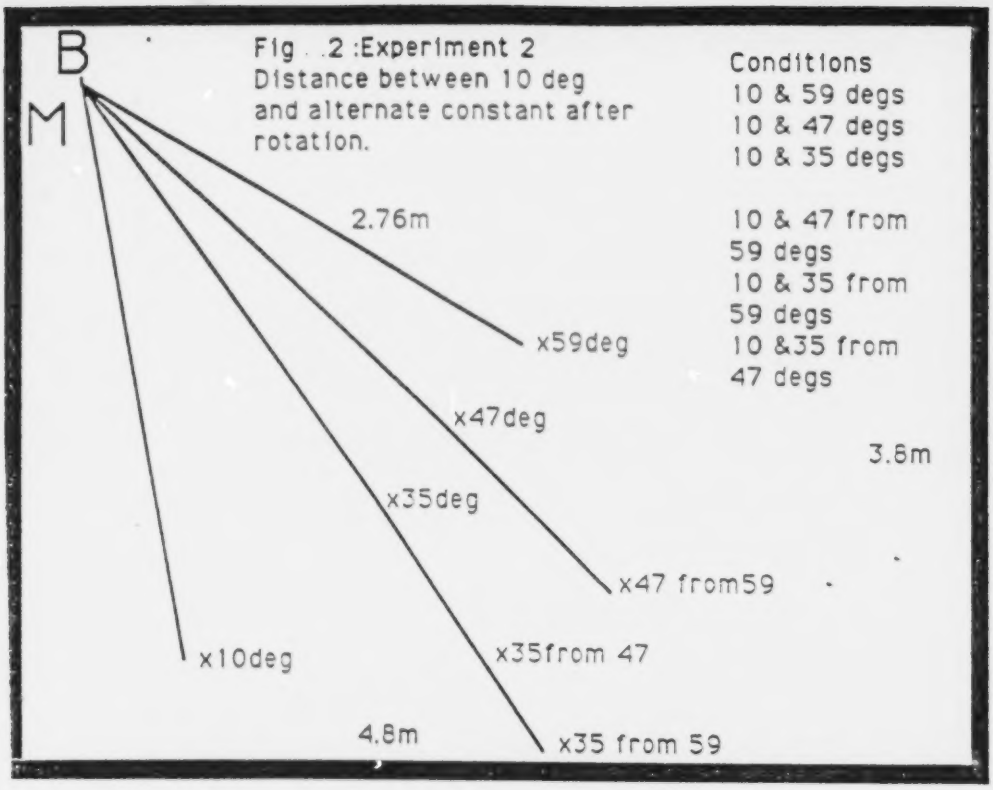
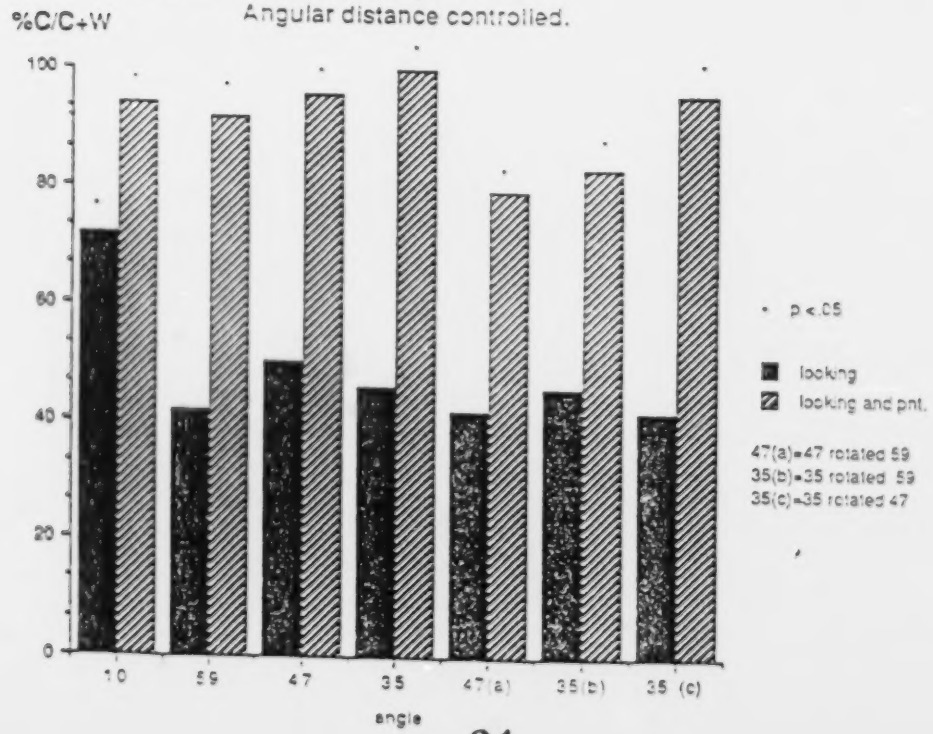
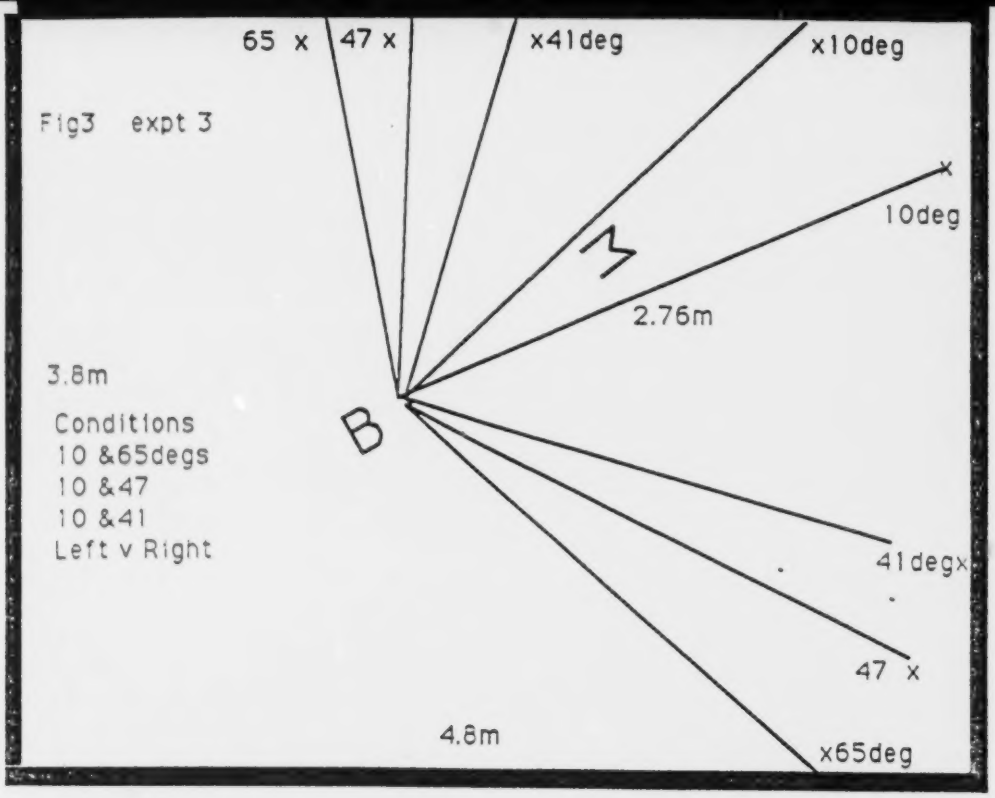


Fig .2a Geometric compensation:
Angular distance controlled.




65 x
47 x
x41deg
x10deg
Fig3 expt 3
x
10deg
M
2.76m
3.8m
Conditions
10 &65degs
10 &47
10 &41
Left v Right
B
41degx
47 x
4.8m
x65deg

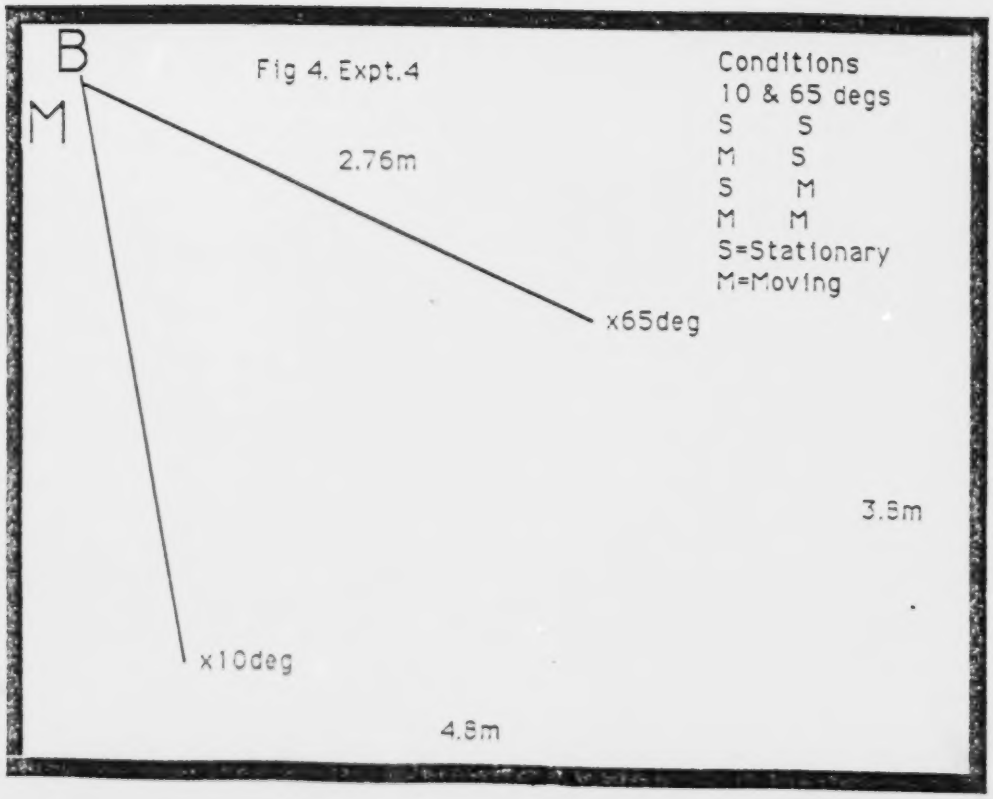

B
M
Fig 4. Expt.4
Conditions
10 & 65 degs
S S
M S
S M
M M
S=Stationary
M=Moving
2.76m
x65deg
3.8m
x10deg
4.8m

Fig 3a Comparison of performance to left of visual field by age, adult looking and pointing.

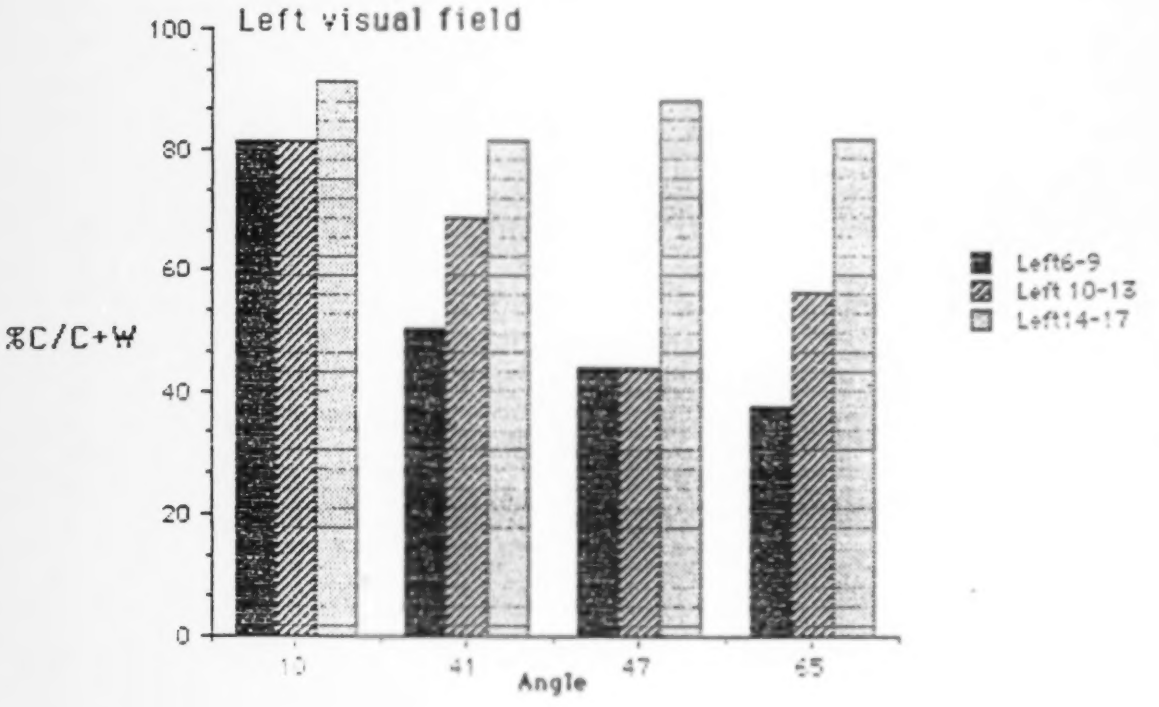


Fig 3.b Performance to right of visual field. Adult looking and pointing.

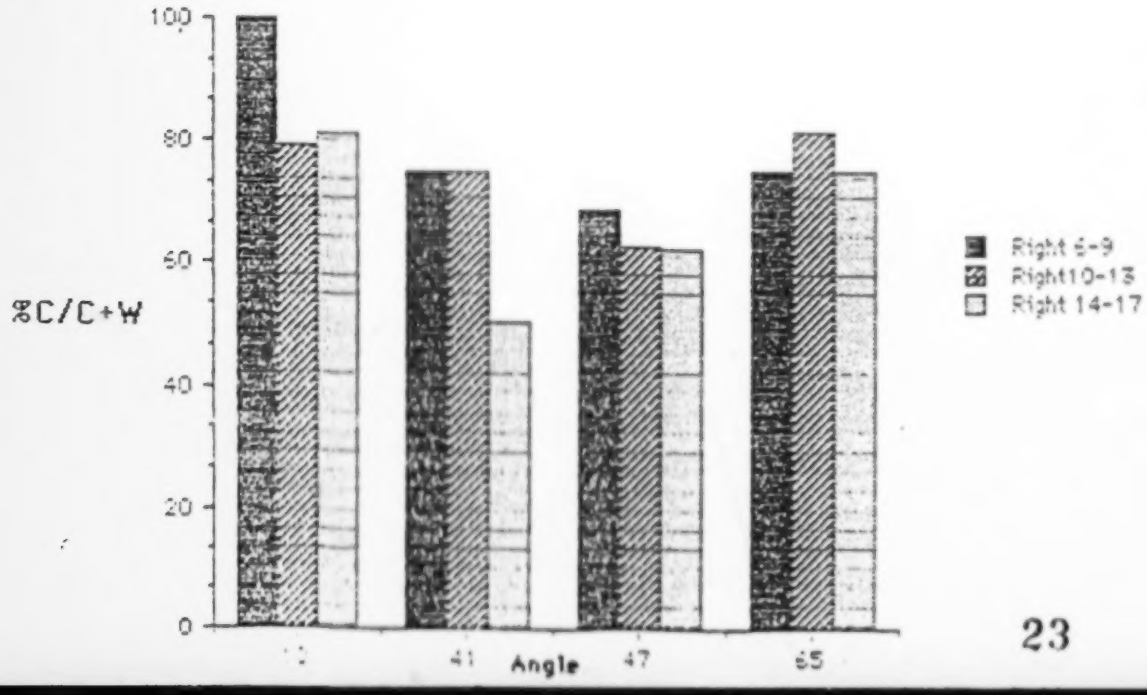


Fig 4 Effects of movement on spatial localisation